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Memorandum

From: Steve Willis
To: Wayne Miller
Date: November 30, 2016
Subject: UXO Pro evaluation of the Air Force's 17 November 2016 response to regulator comments regarding ST012 SEE to EBR Transition and request to continue groundwater extraction (Letter, 29 September 2016).

Wayne:

The following comments were prepared in response to the November 17, 2016 letter from the Air Force regarding the regulatory agencies' concerns with the transition from SEE to EBR. Comments are included on the following pages.

Please contact me if you have comments or questions.

Thank you,

A handwritten signature in cursive script that reads 'Steve Willis'.

General Comment

The referenced Air Force letter (“AF Letter”) makes several assertions as fact that were previously questioned or rejected by ADEQ in comments on the Draft Addendum #2 Work Plan and on the application of transition criteria from SEE to EBR. The concerns were not adequately addressed in the Air Force response to comments, and remain as enumerated and discussed in the specific comments below. Hence, the Air Force letter does not move the project forward.

The request to abandon or delay groundwater extraction for containment is counter to regulatory concerns regarding contaminant migration. The specific comments #1 and #2 demonstrate that contaminant migration is likely occurring and therefore active extraction should be initiated as planned. Delay of the extraction is not consistent with the spirit of discussions in Monthly BCT meetings regarding potential contaminant migration.

Specific Comments

1. Page 2, first paragraph. The AF Letter states: *“As documented in the weekly reports, presented in the August BCT meeting, and discussed during the June, September, and October BCT conference calls, mobile LNAPL has diminished in all zones”*

ADEQ Response:

Mobile LNAPL has not likely diminished in any of the zones other than the small volumes removed from wells. LNAPL appearance in monitoring wells has diminished because the driving pressure gradient to move the LNAPL into wells (i.e., drawdown) has diminished. This phenomenon was anticipated as described in the EPA/ADEQ letter of May 3, 2016:

“1.c. LNAPL columns likely reside in extraction well casings. The bottom of such LNAPL columns may exist above the pump intakes because of limited drawdown and therefore LNAPL does not appear in jar tests. This LNAPL is not recovered by pumping but can supply vapors for extraction. If so, the persistence and increase in vapor mass recovery indicates this LNAPL is being replenished from a ‘reservoir’ of NAPL around such extraction wells. If the bottom of the LNAPL column is below the top of the screen intervals it is hydraulically connected to the formation for replenishment. Recent mass vapor extraction rates exceed the equivalent of 300 gallons/day of LNAPL. Each casing has a capacity on the order of 50 gallons therefore, if this LNAPL is the source of extracted vapors, the formation is replenishing the LNAPL in the casing as fast as it is removed. The drawdown increased with the cessation of steam injection and likely contributes to the increased vapor recovery rate. If the water levels in the extraction wells are allowed to rise, the vapor mass recovery will likely diminish. That reduction will not be the result of LNAPL remediation but rather hydraulically disconnecting residual LNAPL in the formation from vapor extraction.”

LNAPL columns have been detected in all SEE extraction wells in the UWBZ where educator pumps have been removed. After the initial LNAPL removal event, an additional removal event occurred in eight UWBZ wells. These wells included two former steam injection wells (UWBZ-11 and -15). A third former UWBZ steam injection well located on the northeast perimeter of the TTZ has recently yielded a significant LNAPL appearance (UWBZ-09). In the October 2016

meeting, it was stated “ST012-UWBZ09 sample (dissolved benzene concentration) not indicative of LNAPL in vicinity”; however, this former steam injection well had 1.83 feet of LNAPL measured on October 25, 2016. The reappearance of LNAPL in extraction wells, the reappearance of LNAPL in former steam injection wells, and the rising water table indicate mobile LNAPL has not diminished in the UWBZ and that significant volumes, in comparison to initial volumes, remain.

LNAPL columns have been detected in all SEE extraction wells in the LSZ where educator pumps have been removed. After the initial LNAPL removal event, an additional removal event occurred in four LSZ wells, all located on the perimeter. However, results of LNAPL removal and recovery subsequent to educator pumps being removed from several locations have not been reported. LNAPL has not appeared in any of the former steam injection wells in the LSZ. The reappearance of LNAPL in wells, the large number of extraction wells that have not been evaluated for LNAPL behavior, and the rising water table do not support the statement that mobile LNAPL has diminished in the LSZ. Therefore, significant volumes, in comparison to initial volumes, may remain.

2. Page 2, first paragraph. The AF Letter states: “*Six months of post-steam monitoring results have not indicated contaminant migration in any zone.*”

ADEQ Response:

The basis for this statement is not provided. Post-SEE measures of dissolved benzene concentrations in eight UWBZ wells outside the SEE TTZ, range from 1,800 to 9,000 µ/L. This concentration range is substantially higher than the range measured in four baseline, pre-SEE wells located inside the UWBZ TTZ (200 to 5,500 µg/L). The higher benzene concentrations outside the TTZ after SEE may be the result of loss of containment during SEE, loss of containment after SEE, or the lack of data collection in these areas pre-SEE. Hence, migration may be occurring beyond the UWBZ TTZ that could reach the perimeter monitoring wells over time.

In the LSZ, the benzene concentration has increased in three downgradient monitoring wells and one southern well. These results suggest contaminant migration is occurring in the LSZ.

Benzene concentrations have steadily increased as indicated below (date / benzene):

Well W36:

06/23/16	55 µg/L
07/25/16	360 µg/L
08/31/16	820 µg/L

Well LSZ-52:

07/22/16	0.5 µg/L
09/13/16	14 µg/L

Well W24:

07/27/16	<0.4 µg/L
09/06/16	0.55 µg/L

Well LSZ-47:

07/20/16	3.7 µg/L
10/10/16	6.7 µg/L

Throughout and after the SEE operations, eight perimeter monitoring wells located well beyond the TTZ in the LSZ were monitored for changes in dissolved phase concentration. The table below lists the baseline measures of benzene before SEE and the most recent post-SEE measurement. All eight wells, except for W38 that was nondetect, show significant increases in benzene post-SEE compared to the baseline values.

	<u>Baseline</u>	<u>Post-SEE</u>
W11	84	2100
W12	0.35	3.9
W24	ND	0.55
W30	1500	3100
W34	0.28	0.32
W36	2.4	820
W37	730	10,000
W38	ND	ND

The higher benzene concentrations in the perimeter monitoring wells after SEE compared to the baseline measures may be the result of loss of containment during SEE or loss of containment after SEE. Hence, migration may be occurring in the LSZ that could further impact the perimeter monitoring wells over time and contradicts the assertion that no indications exist for contaminant migration in the LSZ.

3. Page 2, second paragraph. The AF Letter states: *"To date, containment migration has not been indicated by site characterization and monitoring data."*

ADEQ Response:

See specific comments #1 and #2 above. In addition to those wells cited in #2, boring logs from the following post-SEE characterization perimeter borings/wells show evidence of contaminant migration: CZ23, UWBZ28/LSZ51, UWBZ33/LSZ48, UWBZ37/LSZ53, SB19/LSZ61, LSZ43, LSZ44.

4. Page 2, third paragraph. The AF Letter states: *"Post-steam elevated temperatures are highly favorable for EBR implementation. Successful EBR implementation at ST012 is partially dependent on taking advantage of the increased solubility and dissolution of contaminants of concern (COCs) from LNAPL occurring at elevated temperatures. In addition, increased anaerobic degradation at the higher temperatures is currently establishing microbial populations that can be further enhanced for bioremediation of COCs. If extended extraction is used for hydraulic containment instead of establishing EBR reagent distribution, deterioration of conditions favorable to the anaerobic EBR approach will occur due to introducing cooler groundwater and higher dissolved oxygen levels."*

ADEQ Response:

- a. No site data or published research has been provided to support the assertion that elevated temperatures at the site are “highly favorable” for sulfate reduction. However, in general, every in-situ destruction or contaminant extraction technology could benefit from increased solubility and dissolution of COCs from increased temperature. Yet, the solubility of benzene is weakly dependent upon temperature in the range considered. The solubility of compounds with heavier molecular weights (e.g., naphthalene) is much more strongly influenced. Sulfate may increase the solubility of the NAPL slightly as a surfactant. Beyond solubility, the dissolution from NAPL depends primarily upon the bulk mass transfer that in turn is dependent upon the groundwater velocity, the diffusion rate in water, and the interfacial area of contact between the NAPL and water. The diffusion rate is very weakly dependent on temperature in the range considered and the interfacial area is not dependent on temperature. The strongest influence on dissolution that can be imposed is the groundwater velocity. Injecting a sulfate solution periodically will not increase the dissolution rate appreciably other than potentially increasing the driving concentration gradient by a small amount (a subject of current research). In short, the increased temperature provides little advantage for EBR with respect to benzene solubility and dissolution.

This topic was discussed previously in the ADEQ comments on the Draft Addendum #2 Work Plan. In the ADEQ evaluation of the AF response to this comment in Sept 2016, ADEQ stated additionally,

“The AF response states the RD/RAWP modeling uses a local-equilibrium condition at each time step to estimate LNAPL dissolution. This assumption yields the best-case scenario for time of remediation and is highly improbable to occur in the heterogeneous subsurface conditions at ST012 as supported by the variation in site-specific LNAPL dissolution rates in the cited publication.”

- b. Greater dissolution of COCs would provide an increased food source for degrading microbes. However, as stated in the response above, dissolution from NAPL is very weakly dependent on temperature in the range considered and the interfacial area is not dependent on temperature. Furthermore, the existence of this degrading population at this site, under current site conditions has yet to be confirmed.
- c. The post-steam elevated temperatures are extreme, and no credible evidence has been provided for this site to support that these temperatures are “*highly favorable for EBR implementation.*” This is particularly true given the length of time that any surviving site microbes have been exposed to these extreme temperatures. Pre-SEE conditions were likely temperate, and any existing biodegrading bacteria would have been adapted to those conditions. The addition of steam likely killed most if not all biodegrading bacteria that were there. The question remains whether the site has been at a hot enough temperature for a long enough time for a new biodegrading population (one that is adapted to the hot temperatures) to become established. Not enough microbial data from this site has been obtained and reported to know this answer.

Given the current subsurface temperatures, there is a slim chance that there is a microbial population that is adapted to these temperatures and is capable of EBR. However, a thermophilic and degrading population has yet to be proven to exist at the site post-SEE.

Furthermore, another item to address, regarding EBR, is that the process of groundwater extraction will enhance the cooling of this site. Without proper baseline microbial testing, and proper monitoring during the extraction (and subsequent cooling) process, there will be no way to properly demonstrate if or how these cooler temperatures are impacting the in situ microbial population and their ability to biodegrade site COCs. ADEQ requests scientifically appropriate baseline testing and follow-up monitoring of the microbial population, with a goal of maximizing the chance for a viable EBR population.

- d. The continued assertion that *“increased anaerobic degradation at the higher temperatures is currently establishing microbial populations”* is unsupported. Valid data has not been provided to show that anaerobic hydrocarbon degradation is currently occurring, and, if it is occurring, that the rate is actually increasing.
 - e. Since evidence of ongoing anaerobic hydrocarbon degradation has not been provided, it is unclear how changing environmental conditions will actually affect the rate of degradation. Until a baseline is established, describing which microbes are present, what their activity levels are, and what community population sizes are, there is no way to determine the impact of cooler water temperatures or higher dissolved oxygen.
 - f. Sufficient data and supporting documentation for this site has not been provided to support the statement that suggests anaerobic degradation, at elevated temperatures, is or is not superior to more temperate anaerobic degradation at this site. Hence, the current high subsurface temperatures may inhibit degradation making cooler groundwater encroachment a benefit to this complex process.
5. Page 2, fourth paragraph. The AF Letter states: *“Post-steam site characterization available to date does not indicate contaminant migration and does not contradict implementation of EBR. Favorable conditions currently exist at ST012 for EBR implementation.”*

ADEQ Response:

- a. Although *“post-steam site characterization data available to date does not ... contradict implementation of EBR”*, this data also does not support it. Repeated requests for proper baseline microbial testing and monitoring have gone unheeded.
 - b. The last sentence cited above has no scientific basis for this specific site under current site conditions.
 - c. In addition, see specific comments #1 through #4 above.
6. Page 2, fourth paragraph. The AF Letter states: *“As long as contaminant migration is not indicated by characterization and containment monitoring results, the AF recommends the startup of active extraction be placed on hold while Phase 2 data is evaluated.”*

ADEQ Response:

The specific comments #1 and #2 demonstrate that contaminant migration is likely occurring and therefore active extraction should be initiated as planned. Delay of the extraction is not consistent with the spirit of discussions in Monthly BCT meetings regarding potential contaminant migration.

7. Page 2, fifth paragraph. The AF Letter states: *“EBR can significantly reduce if not eliminate our concerns of migration through active remediation. Pump and treat has already been established as an ineffective technology for ST012.”*

ADEQ Response:

No site data or published research has been provided to support this assertion for sulfate reduction. In addition, the ability of EBR to reduce or eliminate dissolved phase migration is highly dependent on the mass and location of NAPL in the subsurface. The volume of NAPL remaining post-SEE is highly uncertain. This uncertainty was described in the EPA/ADEQ letter of May 3, 2016:

“3. Though some efforts have been made to estimate the mass of mobile LNAPL remaining at the site, these estimates are subject to high uncertainty. It appears from contaminant extraction data (i.e., continued removal of NAPL), the NAPL found in numerous wells, and high dissolved contaminant concentrations in many locations, that the remaining NAPL source mass is significant and likely to adversely affect the effectiveness and timeliness of the proposed EBR and MNA remedies. Neither EBR nor MNA are source removal remedies, so they are inadequate to address the remaining NAPL.”

Aggressive pump and treat under heated conditions has not been established as an ineffective technology. This was stated in the EPA/ADEQ letter of May 3, 2016:

“4. The site is still at elevated temperatures from SEE operations, so contaminants are more mobile at this time; continuing the extraction efforts is likely to remove significantly more NAPL source material.”

“The agencies would also welcome a timely consideration of more applicable and cost effective methods for drawdown and LNAPL recovery to replace the current extraction system designed for use during steam injection.”

Previous ADEQ comments have recommended re-evaluating the path forward after compiling the complete Phase 1 and Phase 2 site characterization data. Site conditions have been significantly altered by the SEE operations and do not appear to align with the conditions anticipated when EBR was selected as a “polishing” step for SEE and implementation in zones with limited NAPL mass. EBR was never intended as a method to control plume migration. With a site-specific performance evaluation of SEE and a better estimate for the mass and location of remaining NAPL, re-evaluating the remedial path forward appears warranted.

8. Page 2, fifth paragraph. The AF Letter states: *“there is an opportunity to maximize cleanup progress based on current site conditions and information. The AF recommends continuing our progress towards establishing sufficient characterization and monitoring, while also taking advantage of the opportunity to significantly advance site remediation at ST012 with EBR.”*

As stated in Specific Comment #7, there is an opportunity to maximize cleanup progress based on current site conditions and information using aggressive pump and treat under heated conditions. This was demonstrated at the end of SEE after steam injection was ceased and drawdown increased. The approach has the additional advantage of assuring contaminant migration is prevented.